Interplay between body reflectance and shape to reduce cues to shading in living animal

Olivier Penacchio; P. George Lovell; Innes C. Cuthill; Julie M. Harris

Journal of Vision September 2021, Vol.21, 2089. doi:https://doi.org/10.1167/jov.21.9.2089

Abstract

Many animals, including ourselves, use shading as a cue to shape. Darker coloration on the side of the body facing the light ('countershading') is widespread in the animal kingdom and has long been assumed to offer camouflage by obliterating shape-from-shading cues. The pigmentation counterbalances the gradient of illumination on the body by adopting a darker reflectance on the parts that receive more light. However, while it is clear that there must be an interplay between animal shape and reflectance to deliver the best countershading camouflage, the specific contribution of shape to countershading camouflage has been never studied. Here we explored whether body shape, along with reflectance, contributes to reduction of shading cues in several species of caterpillar. We combined stereo photography and light field recovery to measure simultaneously the shape and reflectance of living caterpillars from six species of moths (N = 84, mean = 14, SD = 8.1), three of which are countershaded. If shape and reflectance are both important, then swapping either on a countershaded species should increase visibility. Using three-dimensional modelling of light, body shape and reflectance interaction, we 'swapped' species' shapes and reflectance patterns and computed the visibility of the resulting 'hybrids' under several ecologically relevant lighting conditions. We found that not only reflectance, but the tight interplay between reflectance and shape drove visibility, particularly for some countershaded species. For these, adopting the shape or the reflectance of another species resulted in a significant increase in shading cues, in visibility, and therefore in the likelihood of predation. Taken together, our data suggest that some countershaded species exhibit a co-adaptation of shape and reflectance to minimize visibility to predators, opening a new avenue of research that considers body shape alongside body reflectance as a fundamental factor underlying how coloration acts as visual camouflage.